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Designing a Latex Effluent Treatment System Using Acid Coagulation Rubber Recovery Tank in Series with a Constructed Wetland

Louden Motina[a]*, Ambe Rex[b], Etchutakang Yvonne[c]

[a]Institute of agricultural research for development, Batoke, 77limbe, Cameroon
[b]Vrije Universiteit of Brussels, Boulevard de la Plaine 2, 1050 Brussels, Belgium
[c]Institute of agricultural research for development, Batoke, 77limbe, Cameroon
[a]Email:loudenmotina@gmail.com
[b]Email: rex.che.ambe@vub.be

Abstract

Agro industries are at the center of Cameroons economy and the Cameroon Development Corporation (CDC) is the country's largest agro producer of natural rubber which cultivates and transforms latex and field coagula into industrial grade materials. An average of 6800 tonnes of rubber is produced at the Tiko factory .This generates heavy quantity of effluent been channeled directly to the surrounding waters, constantly polluting it and affecting the surrounding population, company's image and the ecosystem thus violates Cameroon and ISO 14001 standards. Causing losses of unrecovered rubber, extra charges, sanctions on the company and inability to obtain ISO14001 certification. Therefore it is necessary to design a rubber recovery and effluent treatment system to reduce the damages caused by this untreated effluent. In other to do so we analyzed the existing state, we characterized the waste water and designed a new system taking In to consideration key design constraints like high rubber recovery , use of existing structures onsite , zero energy needed and system efficiency. After analysis of the present state, we recorded the effluent characteristics of, flow rate of 22.2m^3/day, TSS of 1031.4 mg/l, BOD_5 1080 mg/l which are extremely higher than standards. Thus using a formic acid coagulation tank as primary treatment in series with a constructed wetlands as a biological treatment will efficiently remove suspended solid, BOD, COD, phosphorous and, especially to ensure total nitrogen removal.

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* Corresponding author.

By evaluating the formic acid coagulation we recorded 80- 85% rubber recovery, thus a reduction in turbidity, also we sized a horizontal flow constructed wetland using Echinochloa Pyramidalis to remove the high organic load. 2 parallel wetlands of area of 2*293.3 m^2 , dimension (45.3 x 6.5 x 0.6)m , retention time of 1 day , bed porosity of 0.3 made up of fine gravels-sand filter bed with 9 plants per m^2 of Echinochloa Pyramidalis, for a projected final discharge effluent of TSS<30mg/l, BOD_5< 50mg/l. Finally we design using Microsoft Visio and solid works to represent a 3 dimensional view. The use of this design in NR agro industries will recover more of its rubber lost in the effluent and treated effluent is in conformity with ISO 14001 standards thus avoiding all the charges link to pollution and improve its company image.

Keywords: Natural rubber; latex effluent; acid coagulation; constructed wetland; design.

1. Introduction

Natural rubber (NR) processing from fresh latex or field coagula produces a lot of wastes especially waste water (effluent) , most of these industries in Cameroon are situated along public sewer lines that enter the Gulf of Guinea. These water go through mangroves which are reproduction milieu of aquatic organism notably fish, pollution of these water bodies by large volumes of untreated effluent from these industries are potential threats to public health and the environment. The discharge of this effluent into the environment without treatment can cause eutrophication of the receiving water due to rapid bacterial biodegradation of these compounds. High levels of algae nutrients and water plants lead to oxygen depletion in streams and diminish aquatic-animal populations, reduces water quality value for other uses (e.g. drinking, swimming etc.); lack of dilution during the dry season produce obnoxious odor in the neighborhood of factories and run off problems during the rainy season creating health risks to the populations downstream [1]. It is necessary to treat these wastes in conformity with the ISO 14001 norms and the Cameroonian standards before disposal into the environment. At the case study factory in Tiko, southwest region of Cameroon, it transforms latex and field coagula into industrial grade materials namely CNR10, sheet rubber, 3CV and 3CL. According to the CDC manual, tapped latex collected either as liquid (ammonia added) or as cup lumps (field coagulum) is received in the factory, latex is weighed; sieved and then transferred into a bulking tank for equalization of the different clones and concentrations. Water is added to dilute (standardized) the latex to a desired Dry Rubber Content (DRC), and the appropriate amount of formic acid added for coagulation to take place. The coagulum is allowed to mature, after which it is passed through a creeper (calendaring) and then shredder (granulation) for size reduction to form coagulum sheets and pellets respectively. The latter is then put in trolleys and dried in an oven at a temperature of 105 to 110°C respectively, the dried rubber is packaged and stored. Annually an average of 6800 tonnes out of 20,000 tonnes of high quality semi-finished rubber produce by CDC is produced at Tiko factory (19 tonnes per day) and this generates heavy amount of effluent daily [2]. Effluent from the rubber processing factory comprise of water from rubber processing stages (coagulation, calendaring, granulation, etc.), water from equipment and raw materials washing (elimination of impurities). The components of the effluent are substances added during harvesting and processing of the rubber such as ammonia, formic acid, impurities, latex that has not coagulated during the coagulation process, serum comprising of proteins, sugar, lipids, organic and inorganic salts [3]. Different technologies have been used to treat waste water in rubber factories mostly Physical or primary treatment such as ozonation, Electrochemical methods, gas injection technique but are very expensive. Also most commonly used and cheap methods used are Decantation, stabilization, dissolved air flotation but are very slow thus coagulation and flocculation are fast methods despite flocculation being expensive (needs an extra flocculants). Therefore for coagulation to occur, the latex pH must be brought to those of the isoelectric point, proteins of the membrane are supposed to have an isoelectric point close to 4.7 [4] but will however remain in suspension when the pH is out of the isoelectric pH range of 4.7 to 5.2. Coagulation can also result when there is microbial oxidation of the carbohydrates to volatile fatty acids such as formic, acetic and propionic acids [4]. Almost all the processing factories try to recover rubber using one of the methods above and their choices are based on the rapidity of process, construction and operating costs, unchanged properties latex after decantation. The combination of processes such as decantation, stabilization, Dissolved Air Flotation (DAF), coagulation and flocculation brings high recovery rate but the costs of these processes are so high that it is difficult to apply widely **[**5]. However, the removal efficiency of the conventional rubber traps by auto-coagulation was observed to be rather slow in the Tiko factory thus there is a need for the use of acid coagulation as a more efficient, cheap and rapid technique for rubber recovery. Biological treatment make use of Anaerobic and aerobic processes usually applied to treat the wastewater of natural rubber processing due to their low operating costs, high removal efficiency and large amounts of biogas generated this methods where found suitable for the treatment of wastewater of natural rubber latex processing [6]. Some of these biological methods which have been verified are**;** Up-flow Anaerobic Sludge Blanket (UASB) investigated to have a very efficient about 80% COD removal [7], but Due to the use of sulphuric acid in the latex coagulation produce toxic gas of H_2S using UASB becomes difficult thus reduction of sulphite is important before treatment. Biological method incorporated with sulphate reduction system shows about 90 % COD, sulphate removal but method is expensive [8]. Many other advanced technologies have been studied but most of them are very expensive and require the use of energy. Cheap methods of biological treatment are Lagoons which are generally used to remove organic matter in the wastewater of natural rubber latex due to their lowest operation cost and construction costs, However, they show some difficulties for the application on large scale, including: large construction area, long HRT (over 30 days), low removal efficiency of organic matters and nitrogen compounds. Mechanical treatments such as anaerobic filter beds, rotating bio discs and aerated lagoons are currently being used where land is limited [9] but needs energy**.** Anaerobic filter shows a high COD removal of 92% efficiency [10] but unable to remove nitrogen, sulphate etc. and finally Constructed Wetlands (CW) have been used to treat waste water with zero energy and chemicals inputs [11]. This brought great advantage using constructed wetlands to purify natural rubber latex effluents due to its ability to degrade, absorb or filter the pollutants and to take-up nutrients from the wastewater, with no energy use. Constructed wetlands are of two types i.e. sub surface flow and fresh water flow constructed wetland but the subsurface wetlands are generally more efficient and require less land area. They can be horizontal flow or vertical flow based on the distribution of water in the wetland [12]. Constructed wetland have been investigated on different effluents which had a high BOD, COD, and TSS, removal rate of 87–88% [13], and the removal rate were found to average 90.4% for TSS and 62.4% for COD [14]**.** With an engineered designed a constructed wetland utilizes natural processes. The following pollutants are removed organic substances expressed as biological oxygen demand (BOD) or chemical oxygen demand (COD), suspended matter, nutrients (nitrogen and phosphorus), pathogenic microorganisms, heavy metals and organic impurities [15]. Constructed wetlands are designed to mimic natural wetland systems, utilizing wetland plants, once the primary treatment finishes the effluent is forwarded to the

CW which consists of an artificial basin filled with water, substrate and plants. The substrates is a filter (sand, gravel, stones etc.,) whose permeability helps to retain sediments and the waste contain in the sewage to be purify. In purification filters are used at the same time as support for the vegetation and a great number living organisms which creates a medium of many chemical conversions and biological (oxidation) [16] to treat the effluent. A well designed wetland have considerable potential for low-cost, efficient and self-maintaining effluent treatment systems, and has demonstrated high capability to remove nutrients, suspended solids, organic compounds. The case study factory had a failed rubber recovery and effluent treatment unit and is in need of a new effluent treatment system and they imposed the following constraints/ limitations on the new design needed , they need a design that is:: Capable of recovering a greater quantity of rubber in the effluent as possible; function with zero energy input; smaller land surface area needed; capable of using existing facilities; capable of reducing the organic load and nitrogen in effluent to acceptable values before discharge; of low construction, operations and maintenance cost. After brainstorming based on this constraints, there is a need to reconstruct a new system that will recover rubber in effluent and also reduce the biological load to acceptable values before discharges, a biological treatment for rubber latex effluents from CDC Tiko factory. Therefore the objective of this work is to design a natural rubber latex effluent rubber recovery and treatment system, for Cameroon's largest rubber processing factory and to propose a design model that can be adapted in any other factory.

2. Materials and Methods

2.1. Site analysis and Sampling

A site view inspection of the structures put in place for latex effluent treatment was carried out. The effluent samples were gotten from 5 different areas, mixed together and then 1000 ml taken from this mixture to the lab to be analyzed.

2.2. Characterization of rubber processing effluent

Most effluent properties where measured onsite and some parameters where analyzed in the IRAD-Ekona latex laboratory.

- Daily flow rate of effluent, Q_d

Portion of the drainage gutter (1m x 0.6m) through which waste water passed before entering the oil trap was measured as well as the height of the waste water, 0.5m (using a measuring tape). To have an indication of the flow rate, a tracer (colorant from the local market) was dropped at a point in the main gutter and the time it took to cover a given distance was noted (using a stop watch). This vary with days of production.

$$Q_d = V * T \quad \textbf{(1)}$$

Where T= average time of processing per day (2 hours), V = volume

- Temperatures and pH

The effluent samples collected were measured using a thermometer that was attached to the pH meter thus measuring pH simultaneously.

- Total Suspended Solid, TSS (rubber recovered)

Samples of effluent collected in a o.5 ml test tube were filtered, the whole filtrate with paper was weighed and then subtracted from the weighed of filter paper.

$$TSS= ((M2 - M1)*1000*1000)/100 \tag{2}$$

Weight of the filter paper only (g), M2: weight of filtrate + paper after filtering (g)

- BOD_5 and COD

The COD/BOD of effluent was determined by an external laboratory. To carry out this analysis, 500ml of fresh effluent was collected in a 500ml plastic container, allowed to cool, refrigerated at -40C for 2days and later transported in a cooler to IRAD laboratory for COD/BOD determination.

2.3. Physicochemical treatment of effluent by formic acid coagulation

The wastewater collected was sieved initial measurements made and then poured in to plastic bottles of about 1000 mL, a burette filled with 1M formic acid used in the factory for coagulation was titrated to 50 mL of effluent at pH 5.2 and TSC of 768 mg/L, 1120 mg/L and 410 mg/L put in separate beakers, while stirring to a desired pH values of 5.0, 4.8, 4.6, 4.2, 4.0 and 3.8. The samples were homogenized according to ISO 1795 (1992). The extent to which formic acid could treat the effluent and the critical pH of treatment were evaluated by measurement of TSC (mg/L) after treatment .The turbidity measurement was carried out at a wavelength of 420 nm using a spectro photometer and the percentage turbidity removal after the physicochemical treatment was calculated as the percentage ratio of the difference in turbidity after and before treatment to that before treatment, The dry rubber content (DRC) on its part was calculated as the product of the TSC and a factor of "0.92" (CDC manual), representing theoretical 8% non-rubbers and other impurities in field latex.

2.4. Biological treatment of the effluent by horizontal flow constructed wetland

Based on our experience from SOPREC Cameroon in using constructed wetlands for sewage treatment, we also reference Danish constructed reed beds to carry out this design.

2.4.1. Sizing and dimensioning of different components and design parameters

The wetland consist of the following components I.e. Excavated basin (impermeable lining to prevent exit or entry of water), Filter media, Water inlet /outlet /distribution, Water adjustments, Macrophyte.

- Calculation of the area of the excavation basin , A_{hcw}

The area of the HCW is one of the most important economic parameter which is calculated using the notion of a first order rate expression,

$$C_t / C_o = \exp(-k_{BOD} t) \quad \textbf{(3)}$$

$$A_{cwb} = \frac{Q_d}{K_{BOD}} \ln\left(\frac{C_t - C_b}{C_0 - C_b}\right) \quad \textbf{(4)}$$

Where, Q_d, average water flow rate (m^3/d), C_0 influent BOD concentration (mg/l), C_t, treated effluent targeted BOD concentration (mg/l), C_b, background BOD concentration (1mg/l), K_{BOD}, first-order areal rate constant (0.117m/d)

- Retention time of effluent in the wetland bed, R_t

$$R_t = \frac{A_{\text{hcw}} * e * d}{Q_d} \quad \textbf{(5)}$$

Where, A = wetland surface area, m2, e = porosity of the wetland, d= average water depth, m, Q = flow rate through the wetland, m3/day, t = hydraulic residence time, t is defined by equation,

The porosity of the bed is defined as:

$$e = Vv/V \quad \textbf{(6)}$$

Where, Vv and V are the volumes of voids and the total volume, respectively

- Area specific oxygen need, O_{BOD}

We calculate first the oxygen transfer rate O_{BOD} in go_2/m^2d

$$O_{BOD} = (BOD_5 * Q_{av})/A_{HCW} \quad \textbf{(7)}$$

- Calculating the dimensions of wetland (width, length and slope)

With the use of DARCYS LAW we first calculate the necessary crossectional area (A_C) in m^2 of the HCW

$$A_C = \frac{Q_{max,d}}{K_f \frac{dH}{ds}} \quad \textbf{(8)}$$

Where: $Q_{MAX,D}$, is the maximum daily flow (m^3/d), K_f , hydraulic conductivity of the substrate (m/d) =300 m/d, dh/ds = slope of bottom of the bed (m/m)

Slope since no energy is use should be between (0.3 and 0.6) to allow free flow of water by gravity and *possibility of flooding the whole bed for weed control without damaging the reed*s

- Calculation of wetland width, length of wetland

Wetland width is obtained using:

$$W = \frac{A_c}{d} \quad \textbf{(9)}$$

After calculating the width we can then proceed with the calculation of the length by

$$L = \frac{A_{cwb}}{W} \quad \textbf{(10)}$$

- Calculating the treated effluent concentration(C_T)

$$C_T = exp^{\left[\ln(C_{t\backslash A} - C_b) - \frac{K_b * A_{cwb}}{Q_d}\right]} + C_b \quad \textbf{(11)}$$

- Filter media ,Macrophyte, and Pipes

For a good design selected sand and gravels of the following criteria: d_{10} should be between 0.3-2.0cm, d_{60} should be between 50-80 mm, $d_{60/}d_{10}$<4, Clay and silk content should be negligible and <0.5% by weight and grain size < 0.1mm. This will enable us attain a hydraulic conductivity between >200 and <1000. After the filter media is the Macrophyte for Nutrients uptake capacities by a number of emergent, free-floating, and submerged macrophytes have been reported .CWs with emergent macrophytes are widely used in wastewater purification in Cameroon. The use of macrophytes was evaluated and deduced from SOPREC (hybrid-station of purification of waste water using filter-plant cite verte- Yaoundé) to treat domestic waste water and it has been very efficient. We evaluated the use of macrophytes to treat domestic effluent for 2 months. Most of the pipes use are made of varying materials for bringing water to and out of the wetland, distribution of water in the wetland and pipes for aeration of the wetland.

- Diagrammatic representation of design. The design was drawn using Microsoft Visio 2013 and solid works 2020 software.

3. Results and Discussion

3.1. Analysis of the existing state

Based on the site analysis we realized that the case study factory attempts to treat latex effluent by auto-coagulation and a biological (lagoon) treatment system which failed about 2 decades ago due to the inability of the existing lagoon to support the quantity of effluent. The lagoons needed extension meanwhile the factory thus not have such a large surface area as required by the factory's intended design shown below.

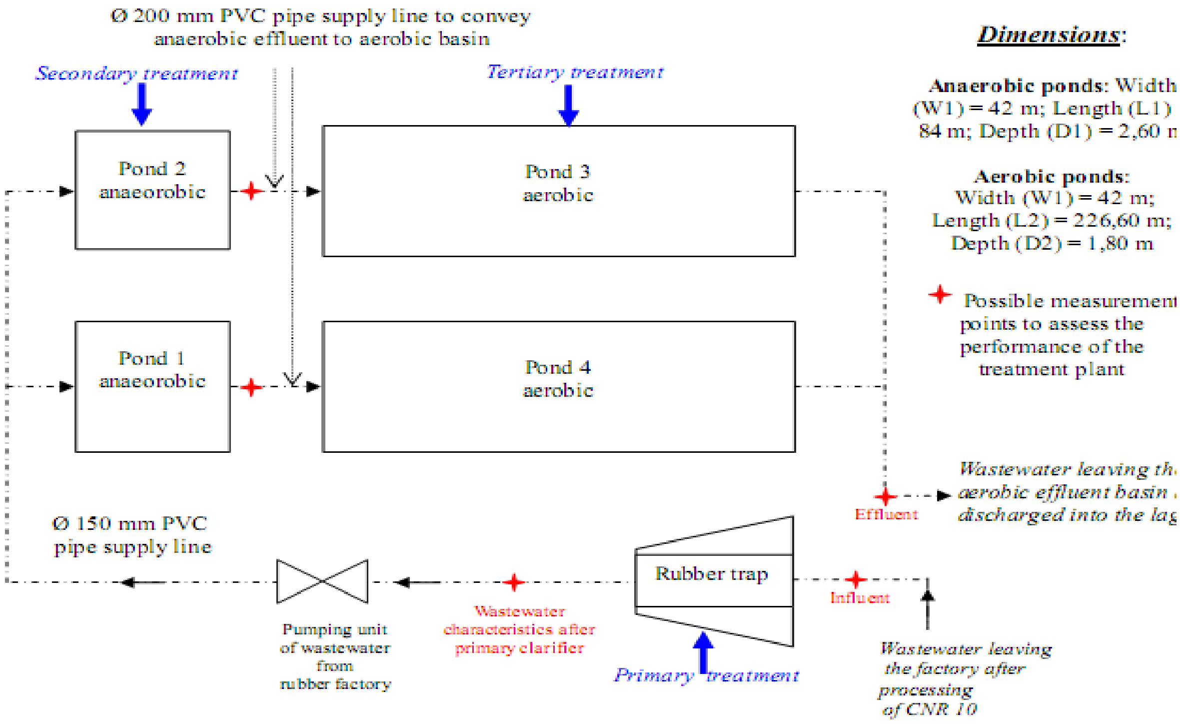


Figure 1: Diagram of the intended effluent treatment plant designed years ago from CDC technical bulletin.

The intended effluent treatment plant was designed since the conception of the factory about 5 decades ago and it required a very large surface area of land which the company could not provide, in other to partially realize the intended design, two rubber traps of dimensions (5.6m x 3.8m x 2.1m) and part of the anaerobic ponds was constructed. Today this units are small and needs extension, which has caused the factory to abandon ponds and it's been used as a reservoir for sedimentation of water from washing of tanks and field coagulum. But the effluent from the process line does not go to this ponds because it can't contain them for 30 days. It is discharged directly from the rubber trap unit. Also the rubber trap makes use of auto coagulation process in which rubber particles and other suspended solids are recovered manually on the surface using a sieve as shown in figure 1. Evaluations and factory reports shows that presently the auto-coagulation process is not efficient, not up to 10% of rubber is trapped due to excess daily water production and less retention time needed for auto coagulation to occur >72hrs. The untreated effluent is then channeled directly into the sea with such high degree of organic load, suspended particles and very low pH. The existing design is no longer useful to the factory and therefore needs a redesign.

Figure 2: View of the existing rubber trap by auto coagulation and the effluent discharged to the environment.

3.2. Characterization of effluent

- Flow rate

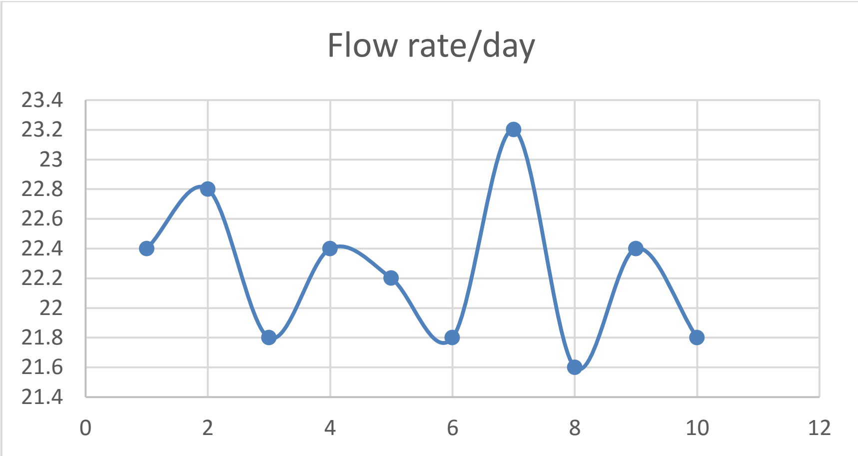


Figure 3: Variation of effluent flow rate.

The average flow rate of the effluent was evaluated to be 11.1 m^3/h, the evolution of volumetric flow rate during production days, representing the variations during working hours. The latex effluent flow for an average of 2 hours daily and the total volume of wastewater discharged daily is estimated at 22.2 m^3.

- pH and Temperature of effluent

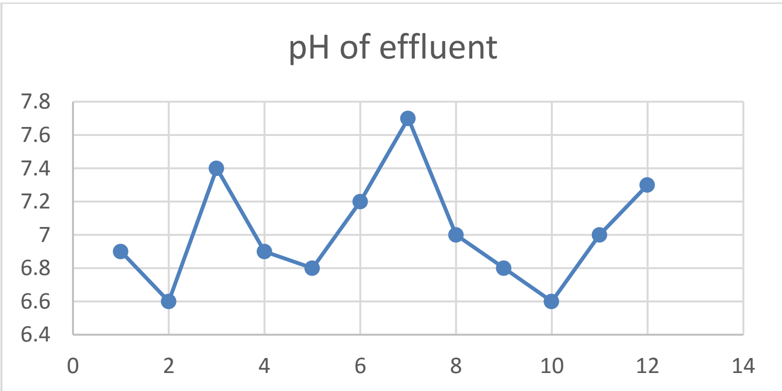


Figure 4: Variations of effluent Ph.

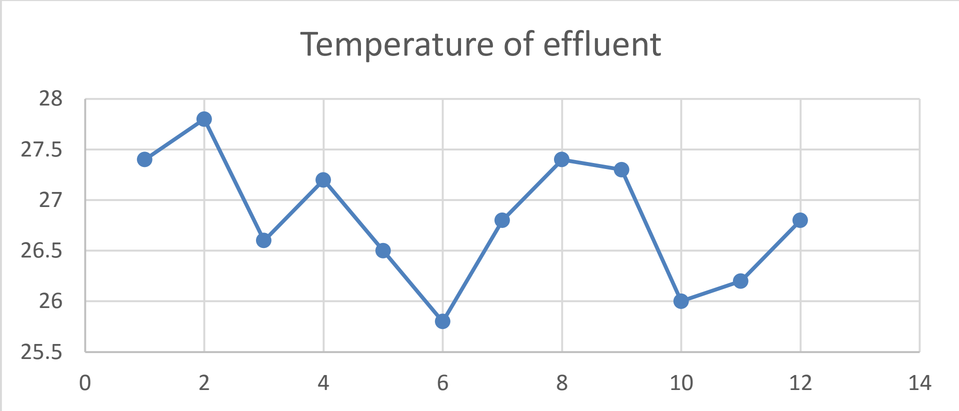


Figure 5: Variations of effluent temperature

The pH and temperature of effluent varies with production days due to variation in coagulations and quality of latex that arrives the factory with an average pH of 7 and average temperature of effluent 26.8 ^{0}c.

- Suspended solid in effluent

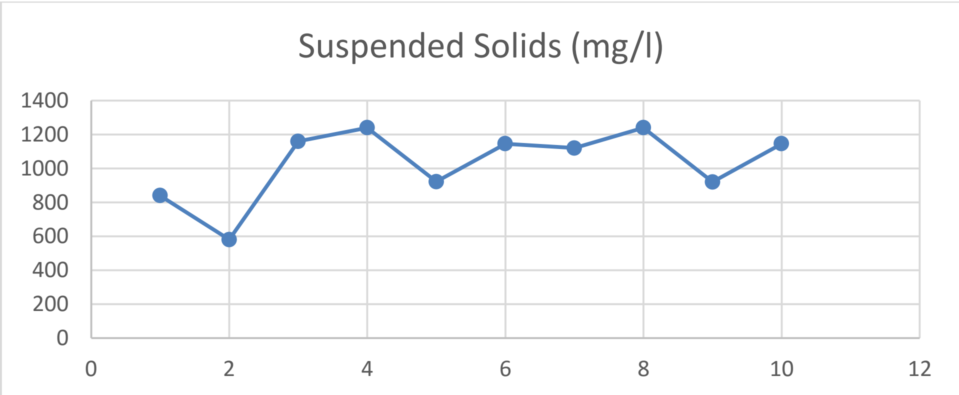


Figure 6: Variations of SS in effluent

The total suspended solids in effluent ranges from 580mg/l to 1240mg/l with an average of 1031.4 mg/l this values are about 35 times higher than Cameroon standards of 30mg/l. This is due to the presence of dirt particles and dust from the field coagulum during shredding and creping, and the processing equipment. The low values were mostly recorded on days when smaller amount of latex crop was received and high values on days when higher amount of latex crop was received.

- BOD and COD

Table 1: values of effluent BOD and COD and Ammoniacal nitrogen

Parameter	BOD5 of effluent	COD	Ammoniacal and total nitrogen
quantity	1080 mg/l	2240mg/l	405.4/1571.3 µg/l
ANOR standards	100 mg/l	400 mg/l	40 µgm/l

From the values obtained the effluent has a very high organic load which cannot be disposed to the surrounding without a biological treatment, this is the main reason the factory had previously put in place 2 lagoons which failed decades ago due to the lack of large land surface to extend the lagoon to contain the effluent for its required long retention time. Also the factory's production rate has increased thus there is a need for a new biological treatment to be designed which should be efficient, economical and zero energy needed.

3.3. Proposed treatment system to design

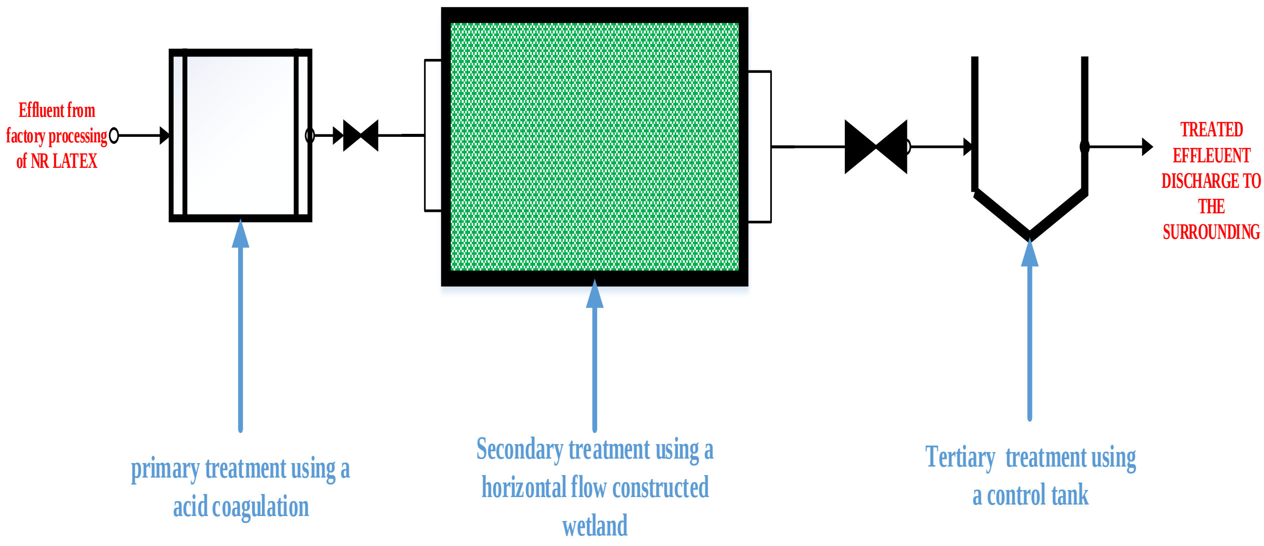


Figure 6: Proposed treatment system to design.

In this system we shall use an acid coagulation tank to recover the rubber which is faster than the auto coagulation practiced and this acid coagulation also functions manually with just the addition of acid to coagulate the rubber particles in the effluent. Acid is available at the factory, the high quantity of rubber recovered by this method is very profitable as to expenses in buying acid or use of auto coagulation. After which the pre-treated effluent will be treated biologically in a horizontal flow constructed wetland, due to ability of effluent to flow through the filter bed by gravity and lesser land area is required with respect to lagoons. The treated latex effluent can be sent to the already existing failed lagoons as a control tank which may will serve as a tertiary treatment since they already exist in the factory and are large enough to store effluent for more than 10 days thus will stabilize the effluent PH and other parameters before discharge.

3.3.1. Coagulation tank specification for design (pretreatment)

Evaluating the performance of acid coagulation, we realized that the removal of effluent's total solids by acid coagulation is efficient, cheaper, faster and easier to operate. The extent (express as percentage removal) to which formic acid would remove total solids from 3 different concentration of latex effluent (1240mg/l, 920mg/l ,580mg/l) at different pH, as well as the critical pH of effluent clarification of each concentration are shown below,

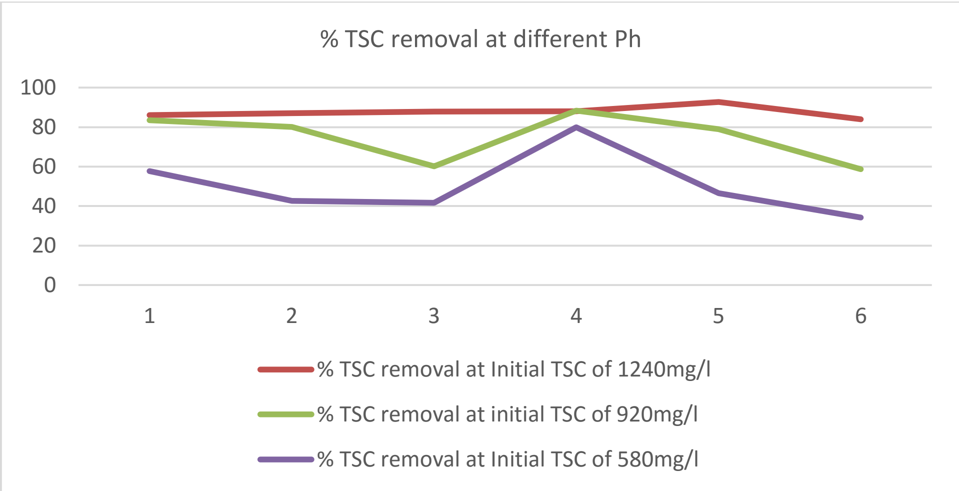


Figure 7: Percentage of TSC removal of different initial effluent concentration using formic acid coagulation at different ph.

The graphs shows an increase in percentage TSS removal with a decrease in pH from 5.2 to a common optimum of about 4.6 for all treatments. The maximum percentage TS removal increases from 78 %, 85 % to 91 % with a corresponding increase in effluent concentration from 580 mg/l, 930 mg/l to 1240 mg/l. From this point, there is a gradual decrease in percentage total solids removal with a further decrease in Ph. Relative to auto coagulation presently used onsite, implementing an alternative method using formic acid coagulation more than 80% of the rubber will be recovered. This makes up 92% of the TSS Thus this will yield a great quantity of rubber recovered compared to less than 20% been recovered presently in the factory using auto coagulation and will generate much money to the company.. We can conclude from this study that latex effluent has an isoelectric pH range of 4.6 to 4.8, which is similar to that of normal latex (4.7 – 5.2).

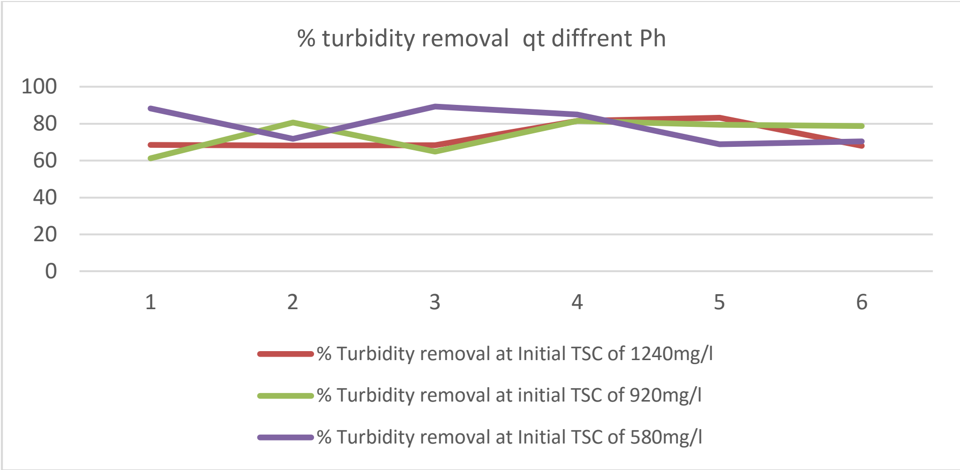


Figure 8: The percentage turbidity removal of different initial effluent concentration using formic acid coagulation at different ph.

Using acid coagulation there is a 60-85 % turbidity removal of rubber effluents of different concentrations. Generally from the figure there is an increase in percentage turbidity removal with a decrease in pH from 5.2 to a common optimum of about 4.6 after which it drops. The percentage turbidity removal increase in effluent concentration from 580 mg/l to 1240 mg/l and mostly decreases from 580mg/l to 930 mg/l .The pretreatment is very important using formic acid coagulation by reducing about 80% of the load of suspended particles in the effluent thus clarifying the water and reducing its turbidity before the biological treatments. Acid coagulation is a faster and efficient pretreatment that can be operated manually, with zero energy needed and acid available in the factory.

- Coagulation tank dimensions

Table 2 below gives the required dimensions or size of a coagulation tank needed since the factory at Tiko needs to do extensions to increase its already existing trap to this size.

Table 2: Dimension of coagulation tank

Parameter	units
Length	3m
Width	2m
Height	3.9m
Volume of inlet drainage gutter	$0.3m^3$
Coagulation retention time	12 hours

Based on the volume of effluent produced above 22.2 m^3 we sized a coagulation tank of dimensions shown above, that will operate in a batch process of effluent retention time for ample coagulation of 12 hours and removal of the coagulum or recovered rubber.

3.3.2. Wetland design specification documents

- Calculated dimensions of the wetlands

Table 3 below gives the specification document of the horizontal constructed flow wetland designed. To guide the realization of the design with exact dimensions and directives.

Table 3: Dimensions of different aspects of the wetland design

Parameter	Dimension
Wetland area, A_{hCW}	586.7 m2 = (2 * 293.3 m2)
A_C	3.9 m^2
Width, W	6.5m
Length, L	45.3m
Retention time, R_t	1 day
Porosity, e	0.3
Slope, dh/ds	0.02
Bed depth ,d	0.6m
O_{BOD}	40.9 go_2/m^2d
targeted treated effluent BOD, C_t	50 mg/l
Inlet and outlet zone gravel size	Coarse gravel 40-60 mm
Grain distribution of gravels filter	Filled fine gravel 10-20 mm d_{60} at top should be between 0.5-8mm
Macrophyte	Echinochloa Pyramidalis 9 plant per m^2
PVC **Pipe dimensions for inlet and outlet and for wetland aeration**	• Inlet /outlet pipe diameter= 500mm • pipe length from coagulation tank = 2m • Inlet distribution structure is a 1m perforated pipe along the width of the inlet. • Pipe length 1m and diameter 180mm is use for wetland aeration per m^2.

The treated water from the CW will be sent to control tank, which will serve as a tertiary treatment. The failed lagoons can be use for this purpose, this lagoons have the ability to store water generated for 10 days that we shall control the temperature, pH and organic load, turbidity before discharge and it will help to stabilize some of this parameters after few days of retention.

3.4. Diagrammatic representation of our design

- **2-Dimensional representation of the treatment system designed using Microsoft Visio**

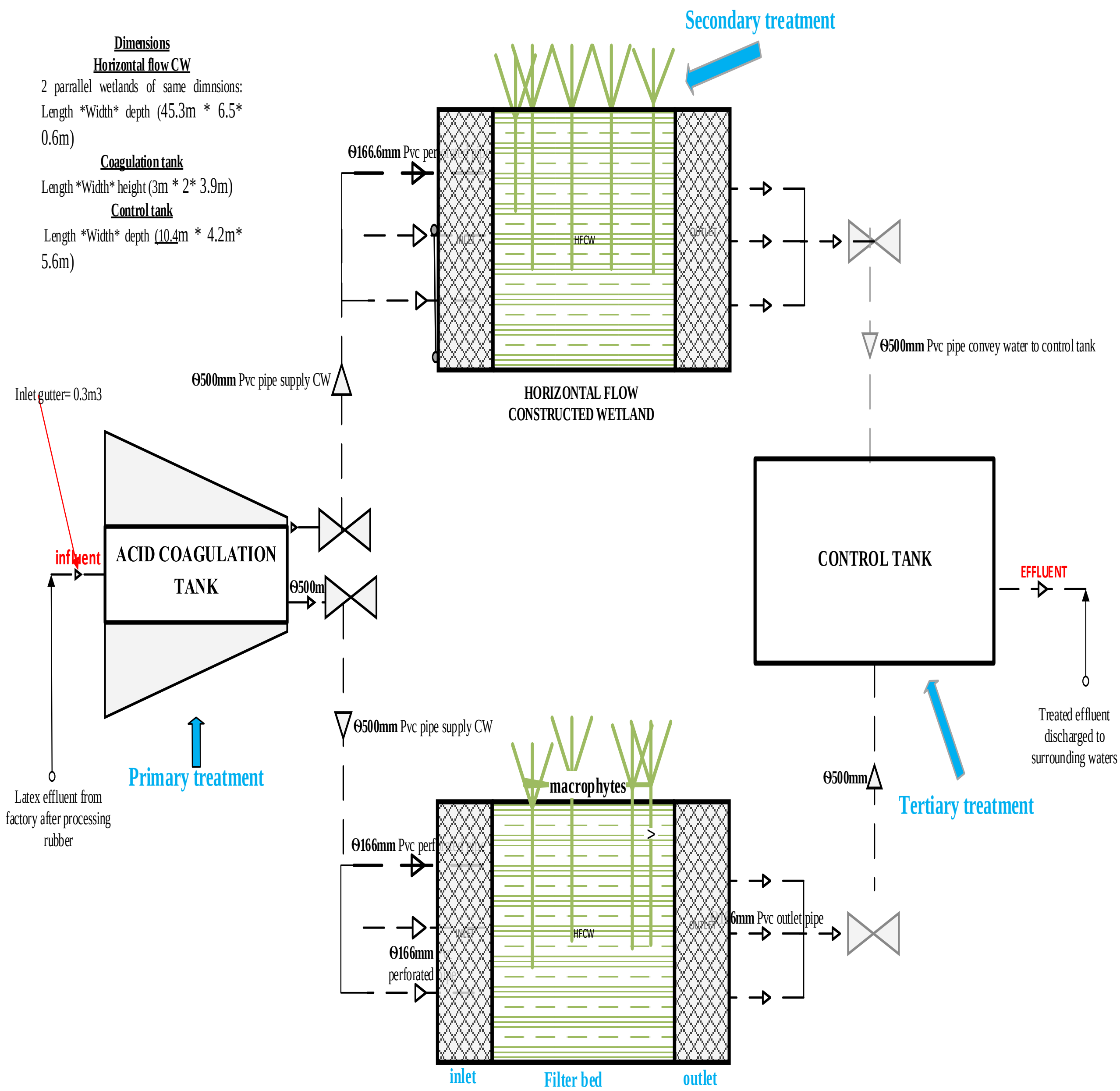
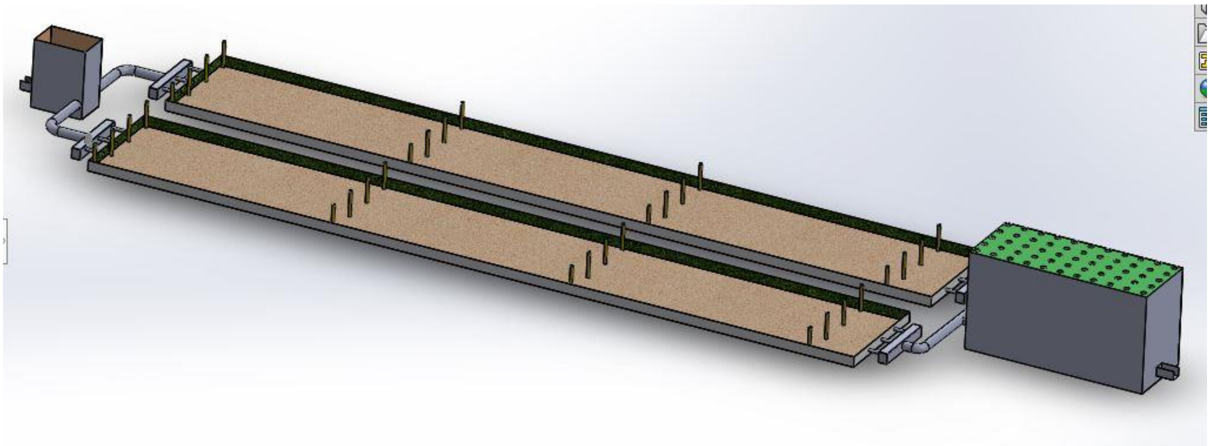


Figure 9: 2 -Dimensional representation of the designed treatment system using Microsoft VISIO 2013.

The representation of the design above shows the different unit operations performed (primary, secondary and tertiary treatment) to treat the waste water from the factory (influent) before it is been discharge to the environment. The influent from the processing of rubber is conveyed buy a gutter constructed with concrete into the acid coagulation tank or rubber trap where the effluent takes 2 hours daily to fill the tank and it will be retain in the tank for 12 hours for coagulation and filtration of the coagulum after which the water is conveyed with a PVC pipe to the horizontal flow constructed wetland where it is retain for 1 day, meanwhile the next batch of effluent is been retain in the coagulation tank. The treated water is then channeled using a PVC pipe to the control tank which has ability to retain water for 10 days so all other parameters are regulated. A 3-dimensional view of the design is shown in figure 10 below to give a picture and ease its realization.

- 3- dimensional representation using solid works



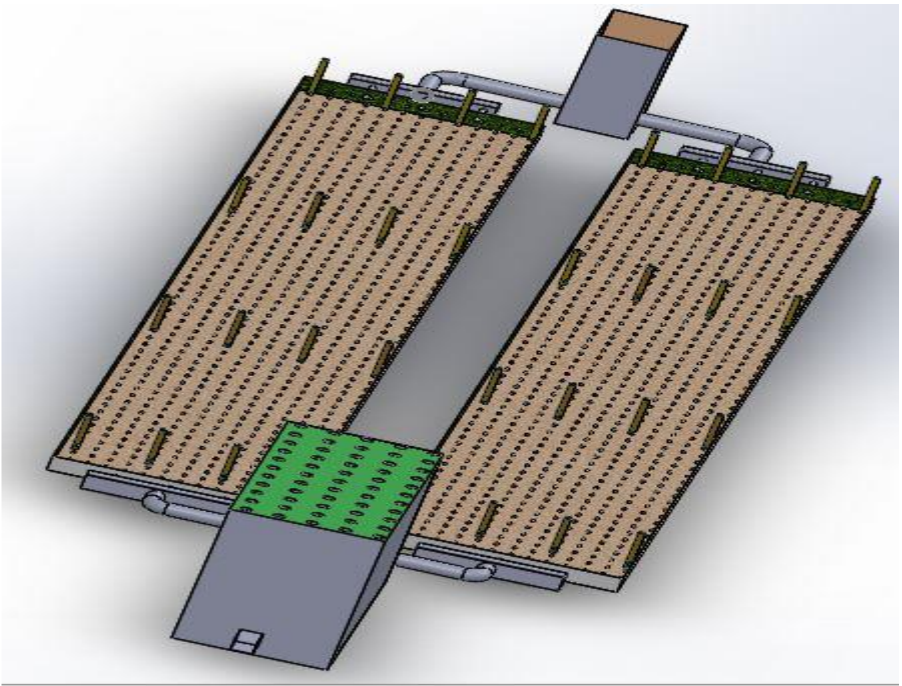


Figure 10: 3 -Dimensional representation of the designed treatment system using SOLIDWORKS 2013

The different views shown above gives a detail picture of the design showing the feasibility of its realisation. It shows the different unit operations connected to each other and the filter bed of fine sand without macrophytes is very visible in the wetland.

- Wetland performance

We expect that using the design, Key parameters of treated effluent before discharge shall be in conformity with ISO standards, this are: pH 5.5-9, TSS ≤ 30mg/l, $BODC_T$ ≤ 50 mg/l, COD ≤ 100 mg/l, TN< 50 µg/l.

4. Conclusion

The objective of this work was to design a cheap and efficient natural rubber effluent treatment system for a rubber processing factory, we started by analysing the state of the case study rubber factory in which we realize the need of a formic acid coagulation been more rapid and efficient as to the auto coagulation used and we evaluated the ideal PH of coagulation obtained to be 4.6 for maximum rubber recovery from effluent. We then sized the acid coagulation recovery tank after which based on the characteristics of the effluent and constraints of the design we sized and dimensioned a horizontal flow constructed wetland for biological treatment of the effluent and finally we diagrammatically represented the design. This design can be adapted to any other rubber factory or agro industry. It can be modified to suite any quantity of effluent generated, very effective and low operation and maintenance cost desired by most companies.

5. Recommendations

For this design to be effective, the wetland maintenance should be regular at least every month to remove clogging at the beds entry and clean bed. Therefore the wetland maintenance is very important and a maintenance check list should be put in place at the factory. Also sufficient slope should be maintained during construction of the design, to enable the effluent to flow easily from factory through the different treatment sectors by gravity.

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